Effects of foot structure on mora duration in Japanese?

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ABSTRACT

We investigated the role of foot structure on mora duration in Japanese. Our initial hypothesis was that moras in foot-final position are longer than moras in the same foot. Ten speakers of Tokyo Japanese read a set of surnames of the form CVCVCVCV, in which the second and fourth CVs were seen to correspond to foot-final moras. The analysis showed no support for foot-final mora lengthening. However, we found evidence for word-final lengthening and within-mora/between-mora duration compensation. Though not conclusively, the results are consistent with the interpretation that the bimoraic foot constitutes a domain of compensation effects of mora duration in Japanese.

1. INTRODUCTION

Japanese speech has long been described as "mora-timed" (e.g., [1]), and at a first approximation the hypothesis of the isochronous mora appears to be justified. Several studies report a linear relationship between word duration and the number of moras in the word, showing that on average moras are of roughly constant duration [2, 3]. Moreover, at least a few studies (summarized in [4]) provide data suggesting that there may be temporal compensation effects, such that moras will compensate for unusually long or short neighbouring moras. These results clearly point to a role for the mora in regulating the fine durational details of Japanese.

On the other hand, it is equally clear that there is no absolute isochrony. Most importantly, intrinsic segment duration effects are found in Japanese as in every other language (fricatives tend to be longer than stops, low vowels longer than high vowels, etc.), and these differences lead to predictable wide variation in mora duration [5]. Second, it has also been reported by several investigators that the syllable-internal position of a mora affects its duration, as moras associated with nasal codas, geminate consonants, and the second position of long vowels are consistently shorter than CV moras [5 - 7]. Finally, there is evidence of unit-periphery effects, such that moras in word-final, phrase-final and utterance-final position are longer than moras earlier in the same word, phrase or utterance [8, 9]. These findings make it clear that, however duration is regulated in Japanese, it is not simply a matter of mora isochrony.

None of the previous studies has examined the role of the bimoraic foot in Japanese speech timing, despite the growing evidence that the foot forms one of the levels in Japanese prosodic structure. So far the evidence for the foot in Japanese comes from templatic conditions on morphological phenomena such as hypocoristics, clipping, and reduplication [10, 11], and the phonetic basis of the foot, if there is any, has not been investigated. We therefore set out to examine the potential effects of the foot on the duration of moras in Japanese. On the basis of earlier studies of factors that affect mora duration, at least two kinds of effects might be expected. On the one hand, we might expect to see unit-periphery effects, such as a tendency to lengthen foot-final moras. On the other hand, we might look for evidence of foot-internal compensation, whereby the duration of moras would be adjusted to compensate for an unusually long or unusually short "footmate."

A pilot experiment suggested that foot-final moras might be longer than foot-initial ones, and our principal purpose in the series of experiments reported here was to investigate the role of position-in-foot on the duration of CV moras. On the basis of our study, however, we have had to conclude that there is no evidence for foot-final mora lengthening, and in that sense the main thrust of this paper is to report a negative result (which we hope may nevertheless be useful to subsequent investigators). However, we also present clear evidence, based on a different methodological approach from the corpus-based study of Warner and Arai [8], that the final mora in a *word* is longer than other moras. We also present more evidence for both within-mora and between-mora compensation effects, providing further proof that the role of the mora in Japanese speech timing is not merely an illusion.

2. EXPERIMENT

2.1 Methods

All our experiments were based on recordings of controlled speech materials read aloud under laboratory conditions. Duration measurements were made on the basis of simultaneous waveform and wideband spectrogram displays on a standard digital signal processing package (xwaves).

Materials. The stimuli were three sets of unaccented CVCVCVCV Japanese surnames. Each set contained 16 names, which included /ma/, /ka/ or /na/ as one of the four

CV sequences. For example, the set including /ma/ had 4 names starting with /ma/, 4 names with /ma/ as the second CV sequence, and so on. The /ma/ set is shown in Table 1:

matsumoto	**ma**suzawa	**ma**tsuzaka	**ma**tsuzawa
shi**ma**kura	ya**ma**moto	ta**ma**mura	ko**ma**zawa
fuji**ma**ki	kita**ma**chi	moto**ma**ki	saka**ma**ki
nagashi**ma**	nakaji**ma**	kawashi**ma**	kageya**ma**

Table 1: Stimuli for Experiment 1 (the /ma/ set)

Following the standard analysis of Japanese phonology that a CV syllable with a short vowel is monomoraic and the foot is bimoraic, each stimulus word was taken to be bipedal, with the structure illustrated in Figure 1. Thus, the second and the (word-final) fourth moras are foot-final.

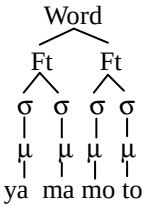

Figure 1: Positions of moras

Subjects. Subjects were 10 native speakers of Japanese from the greater Tokyo area. At the time of the study, they were enrolled in a short-term English program in Edinburgh, UK. All 10 subjects recorded the /ma/ and /ka/ stimuli sets, but only 5 recorded the /na/ set.

Recording procedure. The stimulus surnames were randomized and presented in a list. Subjects were asked to read each name at a normal rate in the carrier sentence *Kare no namae wa* ____ *desu* ('His name is ____'). Each stimulus was read 3 times.

Measurement and analysis. Measurements were made for the first two renditions of each stimulus word that were produced without hesitation or extraneous noise. This yielded 800 tokens per speaker. Mora duration was measured as the duration between the closure of the consonant and the closure of the following consonant. The two measurements were then averaged to give the mean duration of the speaker's production of each stimulus word.

2.2. Results

A three-way ANOVA with fixed factors of speaker, mora position and segment type was conducted for the /ma/ and /ka/ stimulus sets. A significant two-way interaction was found between position and segment type [$F(2, 6)=12.03$, $p<.001$], and between position and speaker [$F(2, 13)=3.85$, $p<.001$. In order to analyze the effects of mora position for each segment type, a two-way ANOVA with fixed factors of speakers and mora position was performed separately for the three stimulus sets. All sets showed a significant interaction between speaker and mora position (/ma/ [$F(2, 27)=5.70$, $p<.001$]; /ka/: [$F(2,27)=2.52$, $p<.001$]; /na/ [$F(2, 12)=2.07$, $p<.05$]. For all sets, there was also a significant main effect for mora position (/ma/ [$F(1, 3)=33.12$, $p<.001$]; /ka/ [$F(1, 3)=8.11$, $p<.001$]; /na/ [$F(1, 3)=37.8$, $p<.001$]). The durations of moras in different positions are given in Figure 2. Bonferroni post-hoc analyses show that for the /ma/ set, the fourth mora was longer than all the others, and the first and second mora were longer than the third. For the /ka/ set, the first and fourth moras were longer than the second. For the /na/ set, the fourth mora was longer than the rest, and the second mora was longer than the third.

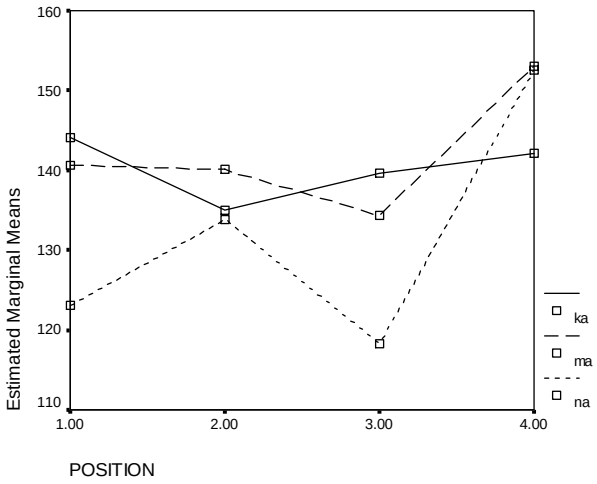

Figure 2: Mora duration in four different positions (ms)

A targeted comparison was made between the duration of /na/ in the name *minakami* and that in *tominaka*. It was predicted that the mora /na/, which is flanked by the moras /mi/ and /ka/ in both names, would be longer in (mi**na**)(kami), in which it occupies a foot-final position, than in (tomi)(**na**ka), where it lies in a foot-initial position. A repeated measures t-test using the mean duration of the two repetitions made by each speaker detected no significant difference in the duration of /na/ between the two words [$t(4)=0.36$, n.s.].

2.3 Discussion

The results present no obvious support for the hypothesis that position-in-foot has a systematic effect on mora duration. If foot-final moras were longer than foot-initial, we would expect to find a pattern of durations like the one we see for the /na/ set, with the second and fourth moras longer than the first and third. However, this pattern of durations is lacking for the other two sets, conspicuously so in the case of the /ka/ set. Since the /ma/ and /ka/ sets are based on 10 speakers and the /na/ set only on 5, the obvious conclusion is that we have not found what we were looking for. This conclusion is strengthened by the result of the paired comparison of /na/ in *minakami* and *tominaka*.

On the other hand, the results clearly point to the existence of a word-final lengthening effect. This effect is statistically robust for the /ma/ and /na/ sets. Word-final lengthening has been reported in a variety of other languages [12], but the results for Japanese so far have been mixed. Based on spontaneous speech data, Warner and Arai

demonstrated that the mean duration of the final two moras of the word is longer than the mean duration of moras earlier in the word [8]. Port et al. looked for word-final lengthening in their study of lab speech and to their apparent surprise did not find it [2]. The results from our study show that word-final lengthening can indeed be observed in careful speech, and that the locus of the effect is the final mora. At the same time, they are consistent with Port et al.'s speculation that in their materials the test word may have formed a "phonological word" with the following mora (the copula *da*) and this may be the reason they found no word-final lengthening.

3. FOLLOW-UP ANALYSES

Summarizing the main results of our experimental study, we find evidence of a small lengthening effect in word-final moras, but we find no support for our original hypothesis that foot-final moras would be longer than foot-initial ones. It does not appear useful to pursue the search for "unit-periphery" effects based on the foot.

In the remainder of the paper we report various follow-up analyses of our durational data that suggest the existence of within-mora and between-mora compensatory effects. Some of these analyses are consistent with the idea that the foot may have a phonetic reality as the domain of between-mora durational compensation, i.e., that one mora may lengthen in order to compensate for an unusually short "footmate" or shorten to compensate for an unusually long one. We emphasize that the data are preliminary, and point out the kinds of data that would be needed to clarify the issue.

3.1 Within-mora duration compensation

Though it is not directly relevant to the foot, we first report evidence of within-mora compensation for variation in segment durations. Although Beckman [5] has cast doubt on the existence of such effects, our data suggest that vowel durations may be adjusted to compensate for differences in consonant duration. We discovered this while trying to understand our failure to find foot-final lengthening. We noticed that the test mora /ka/ appeared to be lengthened in word-initial position (this can be seen in Figure 2), presumably due to initial-strengthening effects of the sort that have been investigated by Keating and her colleagues (e.g., [13]). Such initial strengthening might have overridden any foot-final effects of the sort we were looking for.

Analysis of the first-mora data gives us no basis for "rescuing" our foot-final lengthening hypothesis, but it does suggest the existence of within-mora compensation: it appears that the vowel of the first mora is shortened to compensate for the extra duration of the initial consonant. This can be seen in Figures 3 and 4. In the case of the test mora /ma/, the consonant and vowel durations are consistent in all positions in the word; for /ka/, by contrast, the consonant is longer in first position and the vowel is correspondingly shorter.

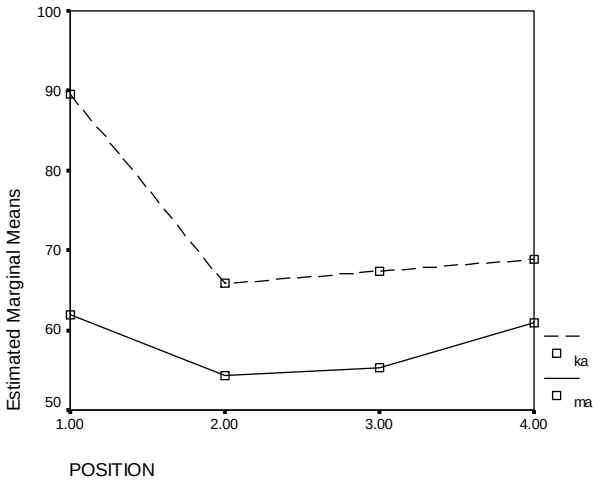

Figure 3: Consonant duration of /ka/ vs. /ma/ (ms)

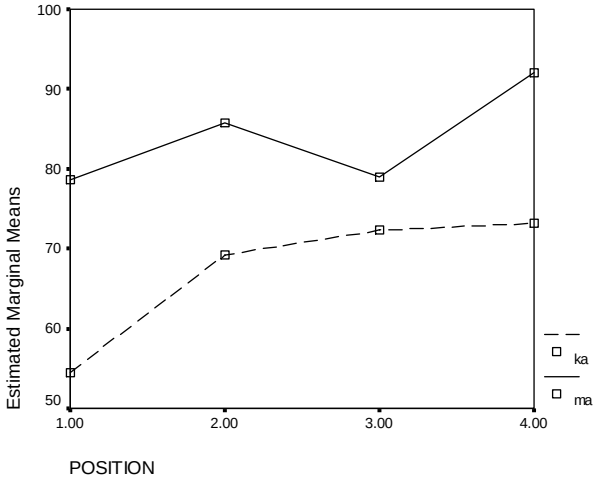

Figure 4: Vowel duration of /ka/ vs. /ma/ (ms)

We are of course mindful of Beckman's caution ([5]) that conclusions of within-mora compensation could be based on measurement error: obviously any variation in the location of the single intra-mora CV boundary will yield a spurious negative correlation between consonant duration and vowel duration. However, this criticism seems less likely to apply in this case, because in all cases the same investigator (the third author) is measuring the same type of CV boundary (viz., the boundary between [k] and [a]) and finds a difference only in one position.

We are also mindful of the possibility that initial strengthening of consonants might affect the durational properties of the [k]: specifically, it might alter the relative duration of closure and release phase. The measurements reported in Figures 3 and 4 were based on CV boundaries placed at the onset of voicing for the vowel, but we redid the measurements locating the boundary at the stop burst. The same difference between first position and other positions in the word was found.

3.2 Within-foot mora duration compensation?

Although the results of our experiment show no support for the hypothesis that there is lengthening of moras at the end of a foot, they do not rule out another potential role of the foot for mora duration, namely, that as a domain of compensation. The idea is that some of the variance in mora duration due to intrinsic segmental duration is compensated for by the duration of the other mora in the same foot. For example, a relatively short CV such as /ri/ in /taritara/ would induce compensatory lengthening of the first mora /ta/ with which it shares a foot, but not that of the third mora /ta/, which is separated by a foot boundary.

Testing this hypothesis requires measurements of moras on both sides of the test moras. Unfortunately we did not design the corpus for easy segmentability, and many of the neighbouring moras had segmental composition unsuitable for measurement (e.g., [wa], [ja]). Nor did we design the stimulus words to include a good range of intrinsic durations in the footmates or non-footmates of the test moras. Given these methodological constraints, we concentrated on a few cases where direct comparisons seemed possible. First, we compared the durations of the mora /ka/ in four names: *katayama*, *kajiyama*, *kageyama*, and *kameyama*. Since it was difficult to place a segmental boundary between the second mora CV and /ja/, we measured the duration of /CVja/ as an indicator of the duration of /ka/'s footmate. To control for the effects of speaker speech rate, we also calculated the mean duration of all /ma/ moras produced by each speaker, as an indicator of their speech rate. A multiple linear regression was performed using the duration of /CVja/ and 'speech rate' as the independent variables and the duration of /ka/ as the dependent variable. The duration of /CVja/ accounted for more variance (17.9%) than did speech rate (5.2%). Assuming that the variance in /CVja/ comes from the variance in the intrinsic segment duration of CV, this shows that there is a relationship between the first and second mora of a CVCVCVCV word. However, it still leaves the possibility that the duration of the second mora also interacts with that of the third mora, i.e., the non-footmate.

Next, we compared the duration of /na/ in *yamanami* and *yamanaka* in order to examine the effects of the intrinsic difference between /mi/ and /ka/. A similar multiple regression analysis was performed using the duration of the fourth mora and speech rate (again calculated from the means of /ma/s) as independent variable and the duration of /na/ as a dependent variable. Against our expectation, the duration of the 4th mora did not account for the variance in the duration of /na/. We suspect that this is due to the effect of word-final lengthening, although the exact nature of the effect cannot be established from this analysis.

4. CONCLUSIONS

Our results provide little evidence that the bimoraic foot in Japanese induces final lengthening of moras. The analyses, however, provide further support for the view that durational compensation occurs both within and between moras. It is possible that the role of the foot is to provide a domain of this compensation such that the trade-off takes place mostly, if not exclusively, between moras that share a foot. However, such effects, if they exist, are likely to be subtle enough to be obscured by the robust word-final lengthening that was observed in our data. This is suggested by the analysis of *yamanami* and *yamanaka* just reported. This means that in order to further investigate the role of the foot in mora duration, we need to examine durations of early moras in longer words, e.g., six-mora words, where the effects of word-final lengthening are not felt.

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